Australian Government
Department of Agriculture and Water Resources

AUSTRALIAN Pork

An evaluation of the nasal ranger for assessment of separation distances for piggeries, and separation distances for piggeries determined by odour dispersion modelling

Final Report
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Tonkin Consulting
Johann Torringer and Chris Purton
5 Cooke Terrace
Wayville SA 5034

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Executive Summary

Establishing a new piggery or expanding an existing piggery involves justifying the resulting odour impacts to the regulatory authorities. The chief of these authorities is generally the EPA of the State where the piggery development is being proposed. The odour impact assessment criteria as well as the required odour impact assessment process vary in the different Australian states, but often involve odour emission sampling, dynamic olfactometry odour sample analysis and odour dispersion modelling. This is often an expensive and complicated exercise. From an industry perspective it is desirable that this process is robust and less expensive than currently is the case. It is also preferable for the industry that odour impact assessments are subjected to assessment against national criteria, given that the piggery industry is a national industry.

One objective of this study was to evaluate an alternative method for assessing piggery odour impacts using the Nasal Ranger for field odour observations at three different kinds of piggeries. The scope of the study is laid out in the project aims below. The Nasal Ranger is a field olfactometer which allows the observer to quantify odour concentrations on site at the time of the observation. The Nasal Ranger works on the principle of splitting the inhaled air into two air streams allowing controlled dilution of ambient odorous air with carbon filtered odourless air.

The project also included an evaluation of the National Environmental Guidelines for Piggeries (NEGP) Level 1 and Level 2 assessment methods for calculation of separation distances by comparison with the field odour observations. With the Nasal Ranger displaying poor performance for piggery odours the field observations were continued with odour intensity observations for odour plume tracking and the weight of the study was shifted to an evaluation of the Level 1 and Level 2 assessment methods for calculation of separation distances. As a part of the evaluation of the Level 2 separation distances determined by odour dispersion modelling comparisons were made of the resulting separation distances of the different Australian State odour criteria. The outcome of this investigative comparison led to the recommendation of the 98th percentile as an odour assessment criterion.

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1. Background to Research

1.1 Evaluation of Level 1 & Level 2 Separation Distances

1.1.1 Issues regarding odour modelling evaluation with observations

The comparison, or rather evaluation, of dispersion modelling results against field odour observations is not a straight forward undertaking for two main reasons.

The first reason for this is that the dispersion modelling result is given for an averaging time while an odour observation is an instantaneous observation of an odour concentration of negligible averaging time. Methods have been devised for this kind of evaluation (Omerod et al., 2002). However, due to the complexity in such an evaluation it was considered that it fell outside the scope of the study. The matter is further complicated by the fact that it has been shown that the applicability of the peak to mean conversion power law is better for statistical analysis of annual data determining peak shorter time averaging concentrations than for assessments of individual observations. This means that the peak to mean relationship applies reasonably well to comparisons of short time observations with longer time predictions for unpaired values while the comparison of paired values gives poor agreement (Hibberd et al., 2007). Comparing observations against individual conditions modelling predictions involves comparing paired values.

The second main reason concerns the accuracy of such an evaluation applied to AUSPLUME. In evaluating model performance for odour observations, the observations have to be matched against modelling predictions for the individual observation conditions. Recent work has shown that AUSPLUME's predicting capability is better in a statistical sense for annual data assessments than for individual hourly assessments, consequently modelling results for individual hours or days can be quite unreliable and say little about the model's performance for annual data assessments (Holmes et al., 2007).

2. Objectives of the Research Project

The project aims listed below were defined in discussions between Australian Pork Limited (APL) and Tonkin Consulting.

1. To determine the effectiveness of the Nasal Ranger field olfactometer in determining odour strengths downwind of piggeries in conditions favouring long distance transmission of piggery odours.
2. To determine the effectiveness of a panel of calibrated noses in determining the extent and intensity of piggery odour travel, particularly at times of minimum dispersion conditions.
3. To compare results of NEGP Level 1 and Level 2 buffer distance calculations against field observations of odour travel and odour levels measured by the Nasal Ranger with piggery odour emissions for the Level 2 assessment calculated from recommended emissions in the APL Odour Research Database, based on pig numbers.
4. To test the effectiveness of the CSIRO TAPM software in determining a synthetic meteorological dataset suitable for input to an air dispersion model.
5. To compare results from the AUSPLUME and CALPUFF dispersion models for outputs of a 1 hour average, 99.9%, 99.5%, 98% and 3minute average 99.9% and 99.5% criteria in order to cover odour criteria for a number of States in addition to the NEGP Appendix A4.6 odour impact criteria

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3. Research Methodology

3.1 NEGP Separation Distance Calculation Methodology

Odour has been identified as the principal community concern in relation to piggery developments. The national odour guidelines for piggeries in Appendix A of the NEGP are based on the best available options for assessing potential odour impacts from the information that is currently available (Australian Pork Limited, 2004). However, each state of Australia has different legislation, codes of practice, policies and guidelines that are relevant to odour impact assessment for piggeries. The NEGP assessment method for calculation of separation distances is staged in three levels of assessment. The first assessment level is based on a standard empirical formula applicable for all piggeries. The second level involves odour dispersion modelling with standard odour emission rates and meteorological data representative of the site, while the third level involves odour dispersion modelling with site specific odour emission rates and meteorological data. With an increasing level of detail in the separation distance calculations from Level 1 to Level 3 the predicted odour impact is intended to be more accurate moving from a Level 1 to a Level 3 assessment. With the Level 1 and Level 2 assessments being more general than a Level 3 assessment the assessment methods for these levels are also meant to be more conservative. Hence, in theory a Level 1 assessment should predict a larger separation distance than a Level 2 assessment which should predict a larger separation distance than a Level 3 assessment.

3.1.1 Level 1 – Standard empirical formula

The Level 1 assessment method uses a standard empirical formula. The method is simple, cheap, quick and offers a high level of protection of community amenity in the separation distance. If a new development of a piggery or an expansion of a piggery cannot meet the level 1 separation distance, odour dispersion modelling for a Level 2 or Level 3 assessment may be required

3.1.2 Level 2 – General odour dispersion modelling

The Level 2 assessment method involves odour dispersion modelling using AUSPLUME with NEGP standard odour emission rates. This assessment method applies to situations where (Australian Pork Limited, 2004):

- piggery design or management is substantially different from the standard design used for the Level 1 assessment;
- meteorological data that represent the site are available; and
- receptor locations are not accurately represented by the Level 1 assessment (ie prevailing winds may increase/decrease potential impacts at certain receptors).

3.1.3 Level 3 – Specific odour dispersion modelling

A Level 3 assessment involves a comprehensive risk assessment, including site specific or site representative information on each of the major variables influencing the resulting odour impact assessment. These are most commonly the meteorological data and the odour emission rates. The model for the odour dispersion modelling can be AUSPLUME or a more advanced model if required. This assessment applies (Australian Pork Limited, 2004):

- to situations where innovative or unusual piggery design or management processes are implemented on-site;
- to piggery sites that are spread over large areas, or have multiple units;

- to piggery sites located in an area with other significant odour sources nearby;
- where particular odour reduction strategies are used; and • where the piggery is located in particularly complex terrain or experiences unusual meteorological conditions.

3.1.4 NEGP odour impact assessment criteria – percentile and averaging time

The NEGP specifies assessment of dispersion modelling odour impact results for separation distances for the 98th percentile for a 1 hour averaging time. The Australian state odour criteria vary from state to state but all states specify higher percentiles. Either the 99.9th percentile or the 99.5th percentile is used (referred to as near maximum percentiles in this report). The NEGP odour impact assessment criteria are presented in Table 1.

Table 1 NEGP odour impact assessment criteria (Australian Pork Limited, 2004)

Receptor type	Odour units (OU)	Percentile	Averaging time
Rural dwelling	3	98^{th}	1 hr
Rural residential	2	98^{th}	1 hr
Town	1	98^{th}	1 hr

3.2 State Odour Impact Assessment Criteria

In the Australian States odour dispersion modelling predicted odour impact is assessed against percentiles of odour concentration values for certain averaging times. The odour assessment criteria vary from state to state. The state criteria for rural dwellings, which are the criteria used for comparison in the study, are listed below in Table 2. The odour impact assessment criteria are derived from state regulatory authorities' experiences on which odour levels at which percentiles and averaging times tend to generate complaints in combination with a conservative assessment approach. Since the criteria are specified for different percentiles and averaging times the resulting separation distances cannot be easily compared without reference to odour dispersion modeling results. Hence the SA criteria of 10 OU does not necessarily allow a higher odour impact and smaller separation distance than the QLD 2.5 OU for instance.

Table 2 State odour impact assessment criteria for rural dwellings

State (Reference)	Percentile	Averaging time	Odour concentration criteria for rural dwelling
SA (Government of South Australia EPA, 2006)	99.9^{th}	3 min	10 OU/m^3
VIC (Victoria Government Gazette, 2001)	99.9^{th}	3 min	5 OU/m^3
NSW (Department of Environment and Conservation NSW, 2006), (Department of Environment and Conservation NSW. (2006a)	99.9^{th}	1 hr	7 OU/m^3
QLD (Queensland Government Environmental Protection Agency)	99.5^{th}	1 hr	2.5 OU/m^3
WA (Government of Western Australia Environment Protection Authority, 2002)	99.5^{th}	3 min	2 OU/m^3

TAS (Tasmanian Environment Division Department of Primary Industries, Water and Environment, 2004)	99.5^{th}	3 min	2 OU/m^3

3.2.1 On percentiles and averaging times in odour impact assessment criteria for dispersion modelling result

The 100 percentile represents the maximum predicted odour concentration for every receptor in the modelling domain and for a one year of 8760 hours of meteorological data input for the modelling assessment, while the 99.9th percentile represents the 9th highest predicted concentration, the 99.5th percentile represents the 44th highest predicted concentration and the 98th percentile corresponds to the 175th highest concentration. The averaging time specifies the time over which the odour concentration is averaged. In dispersion modelling result predictions for averaging times shorter than one hour a peak to mean relationship, determined by the power law below, is utilized for calculation of the shorter averaging time period expected highest concentrations. The shorter the averaging time is, the higher the predicted highest concentration is. The conversion factor used in AUSPLUME for calculation of maximum 3 minute average concentrations from 1 hour predictions is 1.82. The exponent p is commonly given the value of 0.2 (Hanna et al., 1982).

$$Conc_{peak} = Conc_{mean} \left(\frac{AvgTime_{peak}}{AvgTime_{mean}}\right)^{-p}$$

3.3 The Project Piggeries

Three different kinds of piggeries were included in the study. By studying different kinds of piggeries, the NEGP separation distances for each category of piggeries could be evaluated. The piggeries in the study were located in the Murray Bridge to Tailem Bend area in South Australia. The exact location of the piggeries and naming details have been excluded from the report. Instead the piggeries are referred to as Piggery A, Piggery B and Piggery C. Information relevant to the study concerning inputs for the calculation of separation distances and odour emission rates are given below in Table 3.

Table 3 The project piggeries

Piggery A	
Type of piggery	Deep litter housing piggery
Effluent scheme	Deep litter system, no effluent ponds
Annual average of pigs	About 14,000
Piggery shed types	Naturally ventilated shelters of the dimension 12m x 40m and 6m high
Piggery layout	2 sites 450m apart with 20 shelters at each site
Situation	The piggery is located in a flat area with rolling rural terrain to the west. The flat croplands around the site are broken up by sparse patches of native bush
Piggery B	
Type of piggery	Breeder piggery
Effluent scheme	Flushing sheds with effluent ponds
Annual average of pigs	About 10,000
Piggery shed types	Naturally ventilated conventional sheds with heating for the suckers
Piggery layout	12 sheds of varying sizes within an area of 175m x 200m with the effluent ponds located 600m to 700m from the sheds

Situation	The piggery is located in a flat area with rolling rural terrain to the west. The flat croplands around the site are broken up by sparse patches of native bush
Piggery C	
Type of piggery	Grower piggery
Effluent scheme	Flushing sheds with effluent ponds
Annual average of pigs	About 23,000
Piggery shed types	Naturally ventilated conventional sheds
Piggery layout	3 groups of piggery sheds within a larger area with the ponds in between the sheds
Situation	The piggery is located in a rolling rural terrain area. The croplands around the site are broken up by sparse patches of native bush

3.4 Nasal Ranger Odour Observations

Early in the study the field observations were focused on odour concentration observations with the Nasal Ranger. After evaluation of these results it was concluded that the performance of the Nasal Ranger is inadequate for quantification of piggery odour. Consequently the odour observations were continued with odour intensity observations for plume limit (odour detection threshold) tracking using the German VDI standard odour intensity scale (Verein Deutscher Ingenieure, 1992) for determining the distance of odour travel.

The field odour observations were carried out by one or two observers registered as sensitive noses calibrated according to the SA EPA test method for sensitive noses (Office of the Environment Protection Authority Department of the Environment and Natural Resources, 1995). The conditions selected for the field observations were meteorological conditions favouring long distance transmission of piggery odours i.e. stable, poor dispersion conditions. From a practical point of view these stable conditions also had to be forecastable so a field trip could be organized with a single day of notice. The Nasal Ranger is a field olfactometer that allows for quantification of odour concentration on site in real time in the field. The Nasal Ranger works on the principle of dilution to the threshold of odour detection. The flow of ambient odorous air is controlled and diluted with carbon filtered odourless air before the air is inhaled and assessed by the observer. The observer starts with a large fraction of diluted odourless air and assesses higher odour concentrations of air till the detection threshold is reached. The dilution to threshold (D/T) assessment levels are 2, 4, 7, 15, 30 and 60. These D/T levels' corresponding odour units are shown in Table 4.

Table 4 Relationship D/T to odour units

D/T	OU
60	61
31	31
15	16
7	8
4	5
2	3

The sampling starts at the 60 D/T and proceeds to the lower D/T. As odour is detected the D/T is an indicator of the lowest possible odour concentration in the sample range between the D/T that is being assessed and the D/T above. i.e. detection of odour at 15 D/T indicates odour in the concentration range between 16 to 30 odour units.

3.5 Odour Intensity Observations

The focus of the odour intensity observation differed from the Nasal Ranger observations in that the sole purpose of the odour intensity observations was to assess the distance of odour travel till dilution to the odour detection threshold. The aim was to conduct these observations in the worst possible dispersion conditions for comparison of the distance of odour travel till the detection threshold against the odour dispersion modelling results for the NEGP Level 2 and state odour impact assessment criteria, as well as the Level 1 NEGP separation distance.

The piggery odour plumes were tracked downwind from the odour sources. The odour plumes were traversed diagonally to keep track of the plume centre line and edges till dispersion of the plume to the detection threshold. Alternatively the odour plume was just followed down wind depending on the conditions (van Harreveld et al., 2005). In the tracking, observation stops were frequently made for observations and logging of odour intensities, conditions and position. The observation record was logged on to a hand held Trimble GPS unit.

The German VDI odour intensity levels are specified according to an ordinal number scale presented in Table 5.

Table 5 odour intensity levels (Verein Deutscher Ingenieure, 1992)

Odour	Intensity Level
Extremely Strong	6
Very Strong	5
Strong	4
Distinct	3
Weak	2
Very weak	1
Not perceptible	0

3.6 Calculation of Separation Distances – Level 1 Assessments

The Level 1 odour impact assessment is based on a standard empirical formula (Australian Pork Limited, 2004):

$$\text{Separation Distance(m)} = N^{0.55} \times S1 \times S2 \times S3$$

N = number of standard pig units (SPU)
S1 = Piggery design factor for estimating odour potential for the piggery design selected for a particular site (*S1=effluent removal factor,* $S1_r$ *x effluent treatment factor,* $S1_T$)
S2 = piggery siting factor for estimating the relative odour dispersion potential for the selected piggery site (*S2=receptor type factor,* $S2_R$ *x surface roughness factor,* $S2_S$)

S3 = terrain weighting factor for estimating the potential changes to odour dispersion in situations where meteorological conditions may be influenced by local terrain influences.

The aim of the Level 1 assessment method is that it should be a cheap, simple and quick method for assessing odour impact. The method should also provide a high level of protection for the community.

The Level 1 method is supposed to be the most conservative method providing the largest separation distance out of the three assessment levels.

3.6.1 NEGP definition of separation distance

Separation distance in the NEGP is defined as the distance from the closest point within the piggery complex to the receptor which can for instance be a town boundary or a residence. The separation distance between a piggery and a receptor is generally the key factor limiting the number of pigs that can be accommodated at a piggery.

3.7 Odour Dispersion Modelling – Level 2 Assessments

The NEGP specifications of the Level 2 odour impact assessment involve odour dispersion modelling using AUSPLUME. The modelling is described as comprehensive or generic with the input of NEGP standard recommended odour emission rate data. The meteorological data should be representative of the site.

3.7.1 Odour dispersion modelling methodology

The NEGP Level 2 assessment methodology was followed using AUSPLUME for the bulk of the odour dispersion modelling work. It was a project aim to also evaluate the performance of CALPUFF but project time constrains limited this evaluation. The meteorological data was generated site specifically as described below for each piggery using TAPM. The generated meteorology was evaluated against observational data obtained within the modelling domain for the same year as the generated meteorological data. For the purpose of evaluation the TAPM generated meteorology the results of dispersion modelling using regional representative observational data was also undertaken.

Generation of Site Specific meteorological data
TAPM was used for generation of site specific meteorology for the odour dispersion modelling for the three piggeries. The generated meteorology was evaluated against weather data from the Big River Pork abattoir located within the modelling domain.

The meteorological data for the piggeries was generated in two runs. The first run generated the data for the Piggeries B and C and abattoir weather station sites. TAPM was configured for the first run with five nested grids with 43 x 45 grid points. The grid spacings for five grids were 30,000 m, 10,000 m, 3,000 m, 1,000 m, 500 m. The data for the Piggery A was generated in the second run. TAPM was configured for the second run with five nested grids with 21 x 21 grid points. The grid spacings for five grids were 40,000 m, 10,000 m, 3,000 m, 1,000 m, 500 m. Site specific adjustments of the topography, land use, deep soil moisture content, sea surface temperatures and deep soil temperatures were made. The topography data was extracted from the TAPM 9 second DEM

Odour dispersion modelling
For the modelling in AUSPLUME a receptor grids consisting of 101 x 101 grid points and 200 m grid point spacings were used for the Piggeries B and C covering a domain of 20 km x 20 km centred on each piggery. For Piggery A, a grid consisting of 101 x 101 grid points and 100 m grid point spacings was used for covering a domain of 10 km x 10 km centred on the piggery. Variable emission files were calculated accordingly to the NEGP standard odour emission rates using the TAPM generated meteorological data.

3.8 Evaluation of Level 1 & Level 2 Separation Distances

Since AUSPLUME is not capable of accurately predicting ground level concentrations on an individual hourly or daily basis the distances at which the odour detection thresholds were detected at were simply compared to the predicted NEGP and state separation distances.

4. Results

4.1 Nasal Ranger Odour Observations

The intention with the Nasal Ranger observations was firstly to assess the Nasal Rangers performance in piggery odour observations and secondly to compare the observations against the Level 1 and Level 2 NEGP separation distances. Unfortunately the Nasal Ranger's performance in observing of piggery odour was found inadequate and comparisons were considered to be inaccurate and inconsistent.

4.1.1 Findings:

- It was difficult to reliably forecast poor dispersion conditions since the study area was large, with no Bureau of Meteorology automatic weather stations (AWS). The area was also subject to local meteorological variations, which differed at the sites of the nearest AWS.
- Unstable or discontinuous conditions due to plume meandering allowed very little time for Nasal Ranger observations, which can require a few minutes for the observer to produce a good observation.
- Due to the dependence on observation conditions allowing sufficient periods of time for observations Nasal Ranger observations had to be made closer to the odour sources.
- The complexity of piggery odour in combination with a background odour inherent in the Nasal Ranger makes detection of piggery odour near the detection threshold very difficult.
- No consistent observations that compared to the odour intensity at the time were obtained. Hence the Nasal Ranger was abandoned in favour of odour intensity observations.
- The time required for each observation limited the field coverage of the observer.
- The study was initially focused on odour concentration observations with the Nasal Ranger for odour dispersion modelling evaluation but this method was abandoned in favour of odour intensity observations as described above.

4.2 Odour intensity observations

The results of the odour intensity assessments of observed distances to the odour detection threshold are presented in Table 6 and plotted in Figure 8, Figure 9 and Figure 10. Plotted observation results are also attached in the Results and Data Appendices (report reference 20060558RA3). The calculation details of the Level 1 separation distances for the project piggeries are presented in section 4.3.

Table 6 Distances to odour detection thresholds

Piggery	Distance from odour source to odour detection threshold (km)	Odour detection threshold distance fraction of Level 1 separation distances for Town	Observation date	Wind speed (m/s)	Wind direction
A	1.5	45%	24/1/2007	Calm-3	S
A	1.5	45%	10/5/2007	2-5	SE
A	1	30%	2/1/2007	3-5	E
B	1	27%	2/1/2007	3-5	E
B	1	27%	9/1/2007	Calm-2	NE

B	2	54%	10/5/2007	1-3	ENESSW
B	2	54%	13/6/2007	3-5	SSW
C	4.5	73%	9/1/2007	3	NNE
C	2.5	41%	9/5/2007	4-5	S
C	1	16%	10/5/2007	Calm	-
C	1	16%	13/6/2007	Calm	-
C	2.5	41%	13/6/2007	2-5	SW

4.2.1 Findings

- Piggery odour was not detected beyond 4.5 km.
- For winter conditions, which theoretically offer the highest odour emissions from piggery treatment ponds, odour was never observed beyond 2.5 km for any of the piggeries in the study.
- For the odour intensity assessments with the almost instant response time of the human nose odour plume limits could be easily assessed in stable conditions.
- With a much shorter observation time requiring less effort compared to the Nasal Ranger, mobility was gained allowing longer distances to be covered by foot for the assessment of the distance of dispersion to the detection threshold. Odour Intensity Observations
- Odour assessments have to be made with the observer on foot in the field. Exposure to conditions is crucial in detecting a minor wind direction change or wind speed increase.
- Early morning observations in stable conditions showed less odour on the ground and as the wind picked up odour started to travel and the odour concentration/impact increased.

4.3 Level 1 Separation distance calculations

The separation distances in Table 8, Table 11 and Table 14 below were calculated accordingly to the methodology for all receptor types based on the number of pigs at the project piggeries at the date of the field observation on the 24th January 2007. The number of pigs for this date was found to be representative of the average number of pigs kept at the piggeries. Only minor deviations in the pig numbers were noted between the observation dates.

The separation distances are plotted in the result plots in the Level 2 assessments section. The separation distances for the receptor types rural dwelling, rural residential and town are drawn as green circles with the town separation distance furthest from the sources. The separation distances are drawn from the centre of the piggery locations with the distance from the centre of the piggery to the furthest odour source on site (piggery shed or effluent pond) added to the radius of the separation distance.

4.3.1 Piggery A – Deep litter housing piggery

Table 7 S factors Level 1 assessment (Australian Pork Limited, 2004)

		S Factor
Deep litter system: pigs on single batch of litter > 7 weeks	$S1_r$	1.00
Deep litter system – litter composted onsite	$S1_T$	0.63

Surface roughness – undulating hills	$S2_S$	0.93
Receptor type – Town	$S2_R$	25
Receptor type – Rural residential	$S2_R$	15
Receptor type – Rural dwelling	$S2_R$	11.5
Terrain - flat	S3	1.00

Table 8 Calculated separation distances

Receptor type $S2_R$	Separation Distance (m)
Town	3,331
Rural residential	1,999
Rural dwelling	1,532

Table 9 Summary number of pigs and SPUs

Pig Class	SPU Factor	Pig Numbers (and SPU)	
		Pig Numbers	SPU
Gilt	1.8	0	0
Boar	1.6	0	0
Gestating Sow	1.6	0	0
Lactating Sow	2.5	0	0
Sucker	0.1	0	0
Weaner	0.5	1,935	968
Grower	1.0	6,379	6,379
Finisher	1.6	7,461	11,938
Heavy Finisher	1.8	0	0
Totals		15,775	19,284

4.3.2 *Piggery B – Breeder piggery*

Table 10 S factors Level 1 assessment (Australian Pork Limited, 2004)

		S Factor
Conventional flush sheds	$S1_r$	1.00
Ponds with separation of volatile solids	$S1_T$	0.90
Surface roughness – limited ground cover, short grass	$S2_S$	1.00
Receptor type – Town	$S2_R$	25
Receptor type – Rural residential	$S2_R$	15
Receptor type – Rural dwelling	$S2_R$	11.5
Terrain - flat	S3	1.00

Table 11 Calculated separation distances

Receptor type $S2_R$	Separation Distance (m)
Town	3,709
Rural residential	2,225
Rural dwelling	1,706

Table 12 Summary number of pigs and SPUs

Pig Class	**SPU Factor**	**Pig Numbers (and SPU)**	
		Pig Numbers	**SPU**
Gilt	1.8	0	0
Boar	1.6	40	64
Gestating Sow	1.6	2,457	3,931
Lactating Sow	2.5	100	250
Sucker	0.1	960	96
Weaner	0.5	2,328	1,164
Grower	1.0	4,752	4,752
Finisher	1.6	301	482
Heavy Finisher	1.8	0	0
Totals		10,938	10,739

4.3.3 Piggery C – Grower piggery

Table 13 S factors Level 1 assessment (Australian Pork Limited, 2004)

		S Factor
Conventional sheds	$S1_r$	1.00
Pond with separation of volatile solids	$S1_T$	0.90
Surface roughness – limited ground cover, short grass	$S2_S$	1.00
Receptor type – Town	$S2_R$	25
Receptor type – Rural residential	$S2_R$	15
Receptor type – Rural dwelling	$S2_R$	11.5
Terrain - flat	S3	1.00

Table 14 Calculated separation distances

Receptor type $S2_R$	**Separation Distance (m)**
Town	6,171
Rural residential	3,703
Rural dwelling	2,839

Table 15 Summary number of pigs and SPUs

Pig Class	**SPU Factor**	**Pig Numbers (and SPU)**	
		Pig Numbers	**SPU**
Gilt	1.8	0	0
Boar	1.6	0	0
Gestating Sow	1.6	0	0
Lactating Sow	2.5	0	0
Sucker	0.1	0	0
Weaner	0.5	2,150	1,075
Grower	1.0	9,105	9,105
Finisher	1.6	10,579	16,926
Heavy Finisher	1.8	0	0
Totals		21,834	27,106

4.4 Odour dispersion modelling – Level 2 Assessments

4.4.1 Evaluation of Generated Meteorology

The TAPM generated meteorology was evaluated against weather data from the Big River Pork abattoir located 5 km south of Murray Bridge. The year 2003 was run because the abattoir data was 99.8% complete for that year. The evaluation of the generated meteorology (presented in Figure 2) with the observations from the abattoir site (presented in Figure 3) showed that TAPM had predicted the wind directions and frequency distribution of wind directions well. What differed in the predictions from the observations was that the generated dataset was lacking wind speeds in the higher wind speed categories. Partly this can be explained by the elevated location of the abattoir weather station on a ridge which exposes the weather station to higher wind speeds than the surrounding flats. A photograph of the weather station is presented in Figure 1. The photo is taken looking west towards the abattoir. The individual wind roses for the meteorological files for each piggery is presented in Figure 4 to Figure 6. The wind rose in Figure 7 is for another set of observations collected by Tonkin Consulting about 5 km east of Murray Bridge in 2001 to 2002 and was used for comparison of results in the study. The meteorological data sets for the TAPM generated meteorology for 2003 and the observations from east of Murray Bridge are attached in the Results and Data Appendices (Report reference 20060558RA3).

Figure 1 Photo of AWS Big River Pork Abattoir – looking west

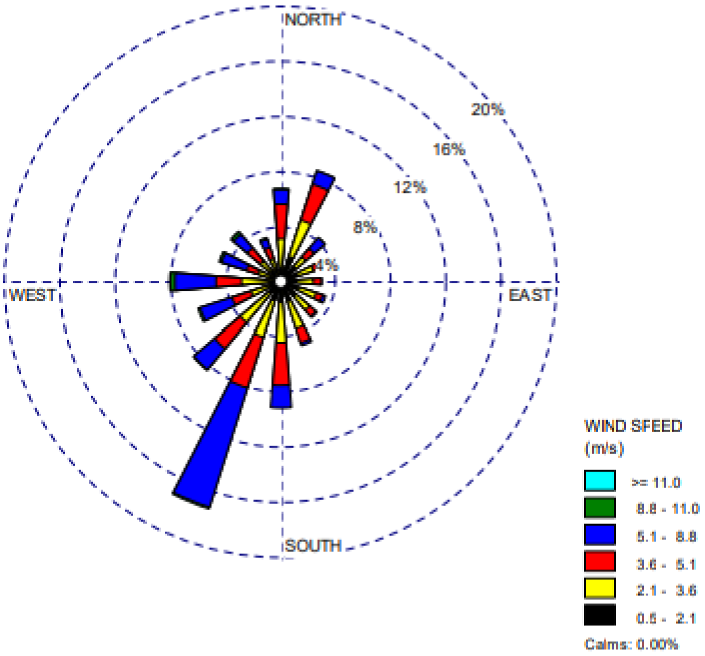

Figure 2 TAPM generation 2003 for abattoir site 100% data availability

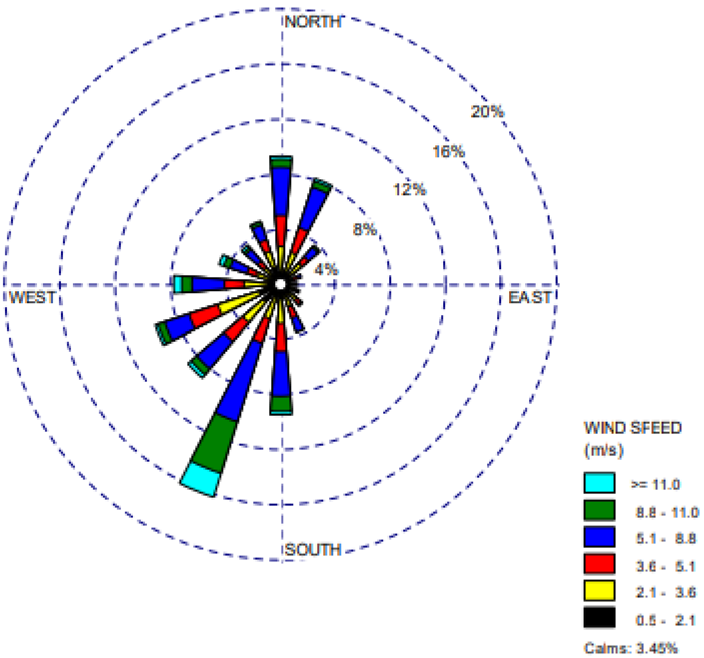

Figure 3 Abattoir AWS observation data 2003 99.8% data availability

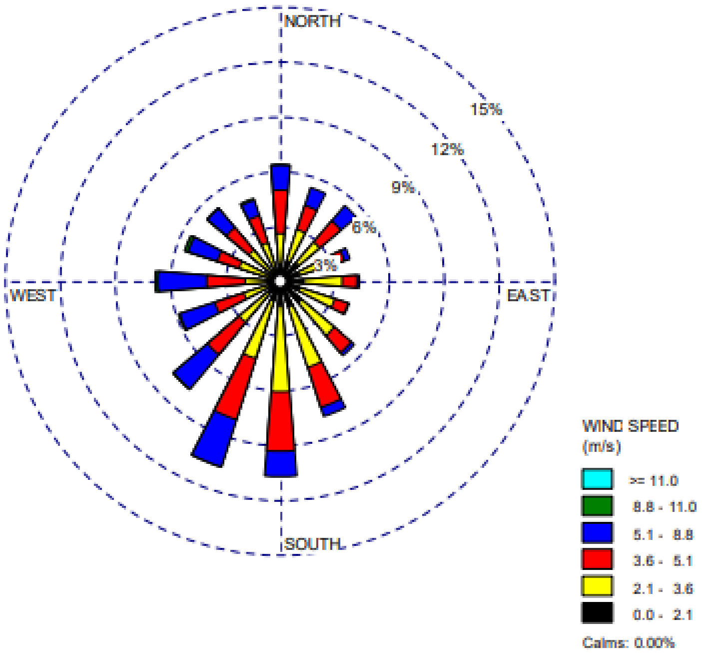

Figure 4 TAPM generated wind rose for location of Piggery A

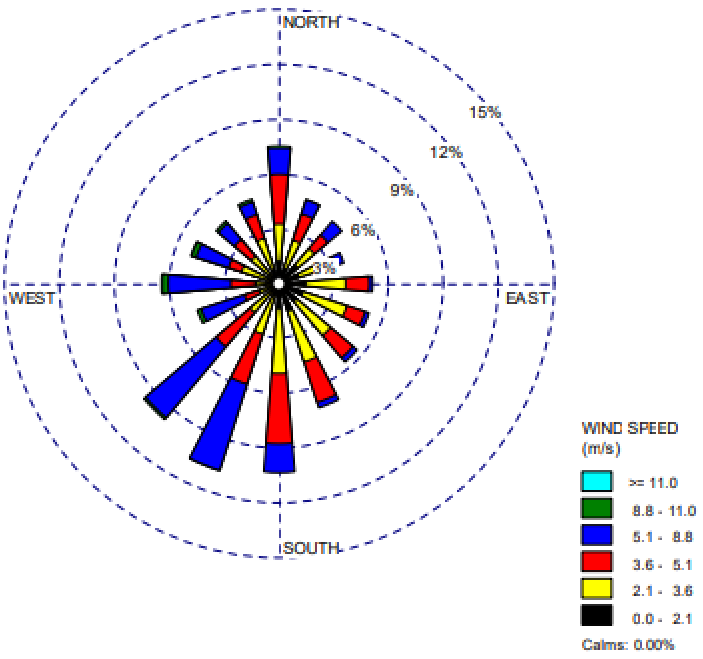

Figure 5 TAPM generated wind rose for location of Piggery B

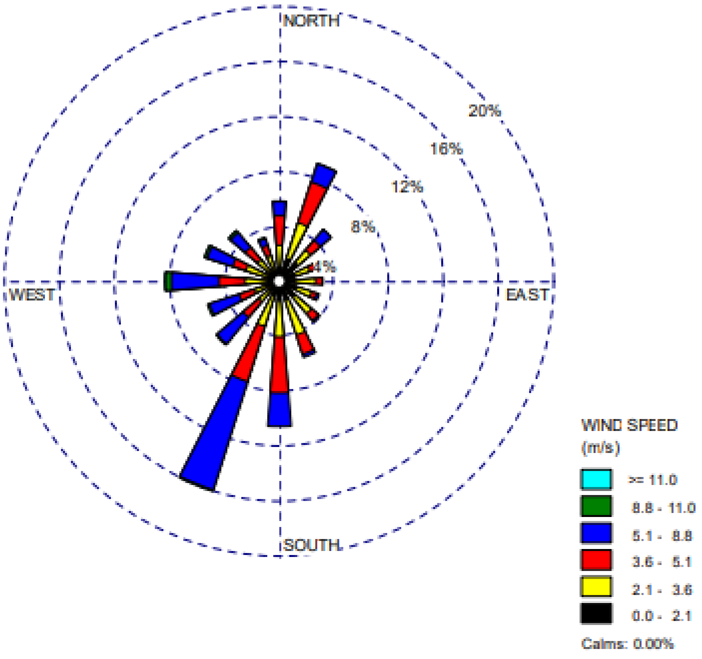

Figure 6 TAPM generated wind rose for location of Piggery C

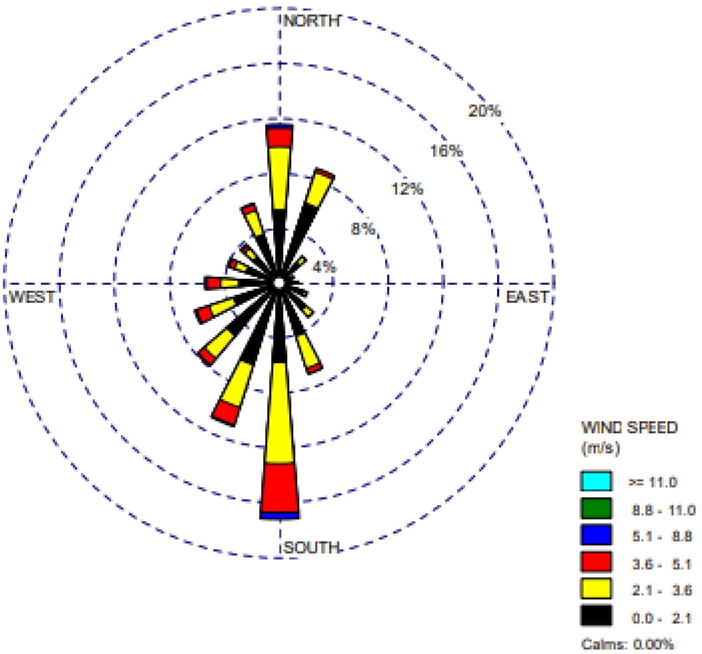

Figure 7 Wind rose for AWS observations east of Murray Bridge 13 months of data for 2001 to 2002

4.4.2 NEGP Standard Odour Emission Rates

Deep Litter Shelters – Piggery A

The NEGP standard odour emission rates for deep litter shelters are temperature dependant and multiplicative factors are given for adjustment according to ventilation methods and shed cleanliness.

For the odour dispersion modelling of the piggery A the temperature dependant odour emission rates for > 7 weeks on single batch of bedding were multiplied with the emission factors for low bedding supply rates &/or high stocking rates were used in the modelling as to represent conditions with higher odour emission rates. The sheds at Piggery A are naturally ventilated.

Table 16 Deep litter shelter odour emission rates (Nicholas et al., 2003)

Odour source	Emission Rate (OU m^3/s per SPU)		
	<10°C	10-25°C	>25°C
≤7 weeks on single batch of bedding	1.25	2.5	3.75
>7 weeks on single batch of bedding	2	4	6

Table 17 Deep litter shelter odour emission factors

Odour source	Situations	Odour emission factors
Ventilation method	Mechanically ventilated shed, temp > 25°C	1.5
Ventilation method	Mechanically ventilated shed, temp < 25°C	1
Ventilation method	Naturally ventilated shed	1
Shed cleanliness	Low bedding supply rates &/or high stocking rate	1.5
Shed cleanliness	Standard bedding supply rate & standard stocking rate	1

The emission factor applied to the emission rates for the Piggery A piggery sheds was:

- 1.5 for cleanliness

Flushing Piggery Sheds – Piggery B & C

Table 18 Flushing piggery sheds odour emission rates (Nicholas et al., 2003)

Odour source	Emission Rate (OU m^3/s per SPU)		
	<10°C	10-25°C	>25°C
Flushing piggery shed	2.5	5	7.5

Table 19 Flushing piggery sheds odour emission factors (Nicholas et al., 2003)

Odour source	Situations	Odour emission factors
Effluent removal method	Effluent removal >6 days, no pit recharge	1.7
Effluent removal method	Effluent removal >6 days, >49mm pit recharge	1
Effluent removal method	Effluent removal <6 days	1
Ventilation method	Mechanically ventilated shed, temp > 25°C	1.5
Ventilation method	Mechanically ventilated shed, temp < 25°C	1
Ventilation method	Naturally ventilated shed	1
Shed cleanliness	Low bedding supply rates &/or high stocking rate	1.5
Shed cleanliness	Standard bedding supply rate & standard stocking rate	1

The emission factors applied to the emission rates for the Piggery B and C piggery sheds were:

- 1.7 for effluent removal system >6 days, no pit recharge;
- 1.5 for shed cleanliness

Effluent treatment ponds – Piggery B & C

The odour emission rates from the effluent treatment ponds used in the odour dispersion modelling were calculated as variable depending on the season, wind speed and stability class. The recommended seasonal emission rates in Table 20 were factored according to the wind speed category and stability classes in Table 21.

Table 20 Base pond odour emission rates (Nicholas et al., 2003)

Season	Base Odour Emission Rates OU m^2/s
Winter	18
Spring	13.75
Summer	9
Autumn	13.75

Table 21 Emission factors for wind speed categories and stability classes (Nicholas et al., 2003)

Wind speed category	Wind speed (m/s)	Median wind speed (m/s)	Stability classes and relative odour emission rates (%)					
			A	B	C	D	E	F
1	0-0.6	0.3	86%	86%	80%	72%	46%	30%
2	0.6-1.2	0.9	149%	149%	139%	125%	80%	52%
3	1.2-1.8	1.5	192%	192%	180%	161%	104%	67%
4	1.8-2.4	2.1	227%	227%	213%	190%	123%	79%
5	2.4-3.0	2.7	257%	257%	241%	216%	139%	90%
6	>3.0	6.5	399%	399%	374%	335%	216%	139%

4.4.3 Level 2 Separation distance calculations

The odour dispersion modelling results of the Level 2 assessment and the resulting separation distances specified by the state odour assessment criteria for rural dwellings and for the NEGP criteria for the three project piggeries are plotted in the Figure 8 to Figure 10 below along with the Level 1 separation distances.

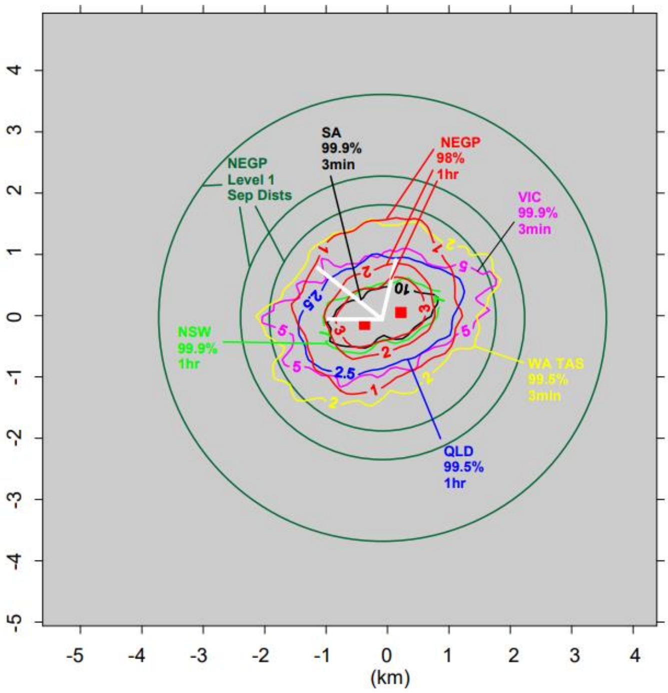

Figure 8 – NEGP Level 1 separation distances, Level 2 separation distances for State and NEGP odour criteria in odour units for deep litter housing piggery – Piggery A 19,300 SPUS. The distances from Table 6 to the odour detection thresholds from the piggery are marked with a white line.

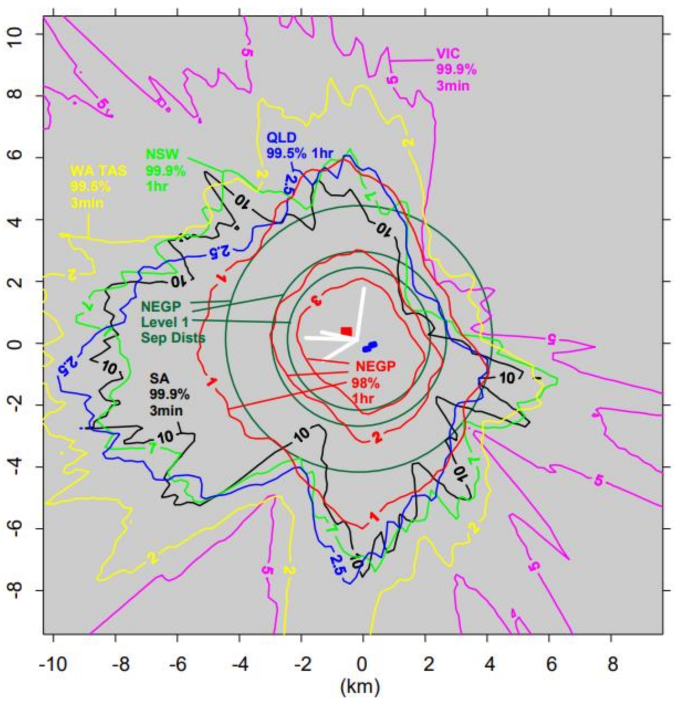

Figure 9 NEGP Level 1 separation distances and Level 2 separation distances for State and NEGP odour criteria in odour units for breeder piggery – Piggery B 10,700 SPUs. The distances, from Table 6, to the odour detection thresholds from the piggery are marked with a white line.

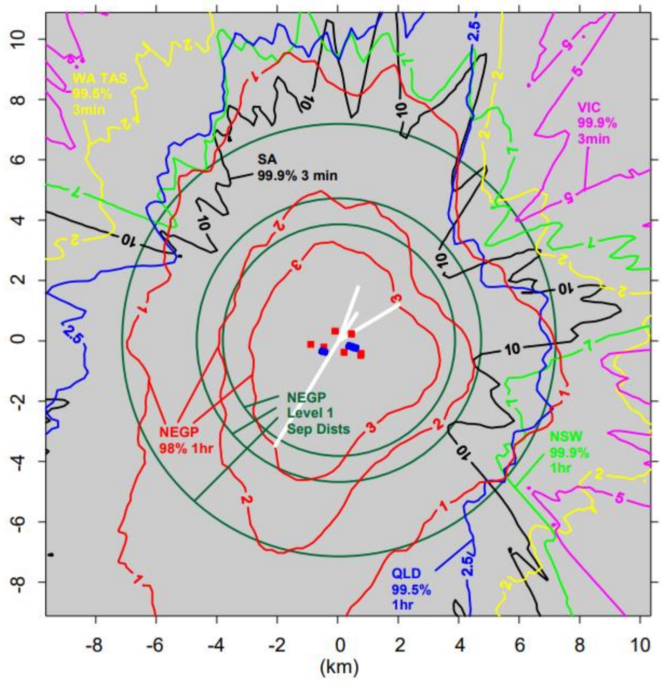

Figure 10 NEGP Level 1 separation distances and Level 2 separation distances dor State and NEGP odour criteria in odour units for grower piggery – Piggery C 27,100 SPUs. The distances, from Table 6, to the odour detection thresholds from the piggery are marked with a white line.

4.5 Evaluation of Level 1 & Level 2 Separation Distances

4.5.1 Comparison Level 1 Separation Distances

The comparison of the greatest distances of odour travel with the NEGP Level 1 separation distances is presented in Table 22.

Table 22 Comparison of greatest observed distance of odour travel against NEGP Level 1 separation distances

Piggery	Greatest observed distance of odour travel	NEGP Level 1 separation distances for each piggery and receptor type		
		Rural dwelling	Rural residential	Town
A	1.5 km	1.5 km	2 km	3.3 km
B	2 km	1.7 km	2.2 km	3.7 km
C	4.5 km	2.8 km	3.7 km	6.2 km

4.5.2 Comparison Level 2 Separation Distances

- For Piggery A the greatest observed distance of odour travel coincided with the separation distances predicted by the Victorian, Western Australian and Tasmanian odour impact assessment criteria for the receptor type of rural dwellings.
- For Piggery B the greatest observed distance of odour travel coincided more or less with the separation distances predicted by the NEGP odour impact assessment criteria for the receptor type of rural residential.

- For Piggery C the greatest observed distance of odour travel coincided more or less with the separation distances predicted by the NEGP odour impact assessment criteria for the receptor type of rural residential.

4.5.3 Findings

- The odour detection thresholds appear to coincide with the NEGP Level 1 separation distances for the receptor type of rural residential. This would appear to confirm that the NEGP Level 1 separation distances do offer a high level of protection of community amenity since odour was never detected at the distance of the town receptor type.
- All of the assessed odour impact assessment criteria appear to overestimate the odour impact and separation distances for piggeries with effluent ponds. The cause for this has been identified as the sensitivity of the NEGP pond odour emission rate scheme to the meteorological data. It is hence no surprise that the 98th percentile predict separation distances that correspond better to the observed odour than the higher percentile assessment criteria. The Level 2 separation distances are supposed to still be conservative compared to a site specific Level 3 assessment, but too much conservatism is being applied.
- The shift in the increased separation distances comparing the NEGP criteria with the state criteria for the deep litter housing piggery and the piggeries with effluent ponds highlights the sensitivity in the assessment criteria to the NEGP pond odour emission rate scheme with the 98th percentile predicting less extreme separation distances.
- The 98th percentile is a less sensitive assessment criterion that produces more reliable odour impact predictions and separation distances.
- The worst odour observation conditions were found comparable to the conditions causing the top 2 % of the highest concentrations or the 98th percentile by comparison with the AUSPLUME meteorological file.

5. Discussion

5.1 Nasal Ranger Odour Observations

5.1.1 Observation conditions

In previous APL projects (project 1980 ñ task 2) it was suggested that odour concentration observations taken with a field olfactometer such as the Nasal Ranger might offer a method for validation of odour dispersion modelling. In the report on APL project 1980 - task 2 “Guidance on Dispersion Model Selection” (Pacific Air & Environment, 2003a) it is pointed out that field observations with a Nasal Ranger might be considered in cases where odour concentrations do not fluctuate significantly.

Stable conditions were preferred for the field odour observations for two reasons. The first reason was that stable conditions give poor dispersion and high odour concentrations. The second reason was that stable conditions with a small variation in wind direction were also required for better observation conditions, conditions which resemble the modelling odour concentration predictions in terms of the concentration averaging time.

It was found that it was quite difficult to forecast meteorological conditions which would favour poor dispersion and non-fluctuating odour concentrations. Climatic conditions from odour complaint histories, if available, might give some indication on specific conditions at the site which produce worst case odour conditions. As local climatic knowledge of seasonal onset and strength of sea breeze was built up the level of successful forecasts was improved.

The main forecast indicators used for selection of observation days were:

- national mean sea level pressure prognosis synoptic scale charts - for indication of gradient wind direction and speeds; and
- coastal waters forecast and forecasted temperatures - for indication of the wind speed and wind direction of the sea breeze.

It was found during the course of the study that the most stable wind directions for the area where the study was conducted occurred when the gradient wind direction coincided with the sea breeze wind direction. Hence synoptic conditions like illustrated in Figure 11 were preferred.

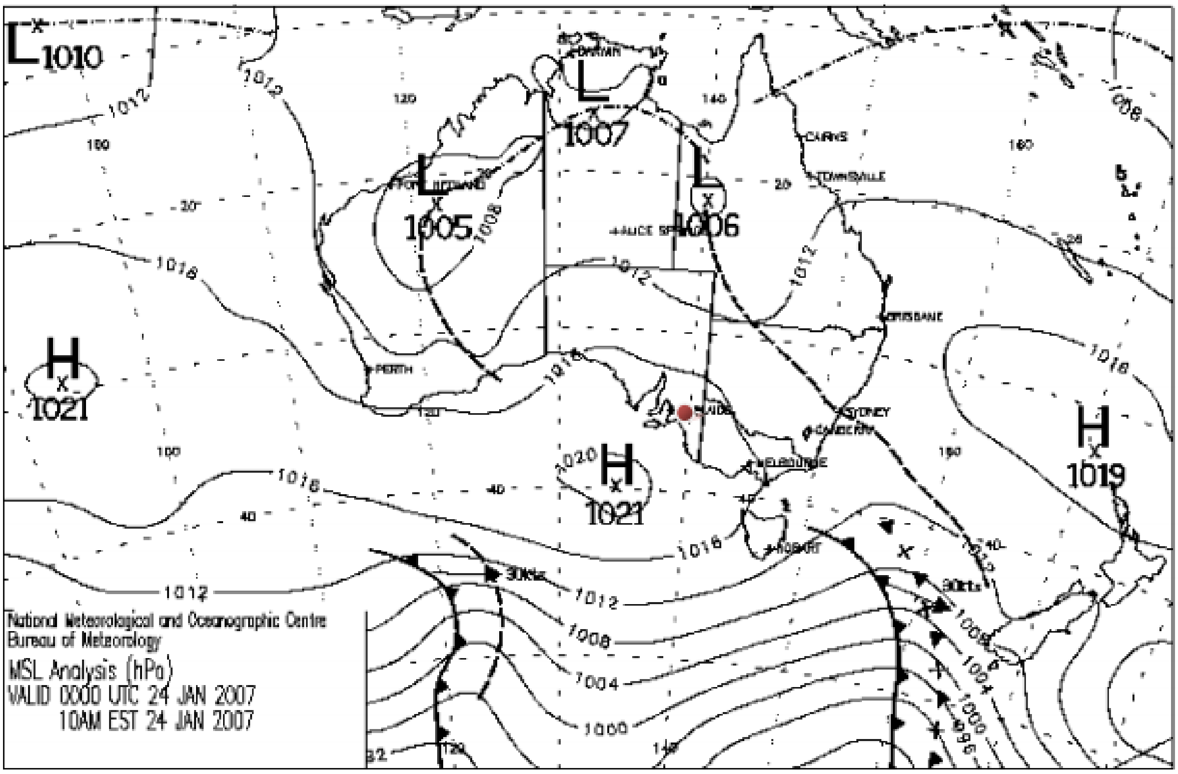

Figure 11 Preferred synoptic conditions for observations in the Murray Bridge area marked by the red dot (Bureau of Meteorology, 2007).

Fluctuations in the piggery odour concentrations experienced by the observer were mainly due to:

- variations in wind directions both for meandering plumes and more consistent sigma theta variations;
- variations in wind speed; and
- possibly variations of odour emission rates due to variations of wind speeds.

These variations made it extremely difficult to undertake an observation in defined conditions for evaluation against dispersion modelling since the exposure time to the odour plume was found too short for an observation with the Nasal Ranger in many cases.

It was found that fairly stable meteorological conditions are a necessary condition for Nasal Ranger observations. An observation cannot be obtained instantaneously with the Nasal Ranger as a calibration of inhalation of odourless air precedes the observation and a there might be a need to assess a few different dilutions before detection. Hence meandering odour plumes or intermittent odours are difficult or impossible to monitor with the Nasal Ranger.

5.1.2 Nasal Ranger performance for piggery odour observation

Another problem with the Nasal Ranger arose because the nose seal of the Nasal Ranger has an odour that masks the piggery odour. Alternative seals were considered but no odourless alternative could be obtained. It was also found that piggery odour is a complex odour that does not give a sharp point of detection in the Nasal Ranger, and this condition was made more difficult given the masking odour arising from the nose seal.

The Nasal Ranger is manufactured out of plastic. According to the Australian Standard on determination of odour concentration by dynamic olfactometry the materials odour sampling equipment is to be made out of are: teflon, stainless steel, glass, tedlar and PET (Australian/New Zealand Source Emissions). Most parts of the Nasal Ranger fit this requirement (St Croix Sensory Inc., 2004). However the Nasal Ranger and the nasal comfort seal in particular ware found to have an inherent smell masking the piggery odours and making detection difficult.

There is also a potential for desensitization to piggery odour over time and exposure in the field. Attempts were made to address this issue by carrying carbon filter masks as a remedy. However, the masks were found to have too much of a plastic smell to offer a neutral nasal odour environment.

A factor contributing to the difficulty of obtaining observations with the Nasal Ranger is that the Nasal Ranger requires the full attention of the observer for the moment of observation. In a practical sense this is difficult to achieve in a field observation situation while at the same time keeping in mind the direction of source, the wind direction, the wind speed and noting changes in the wind speed and wind direction while at the same time logging observations.

Informal discussions with operators in the Australian odour industry at the CASANZ 2007 Conference indicated that the collective opinion is that the Nasal Ranger is difficult and unreliable to work with.

Due to the poor results of obtaining field observation of odour concentration with the Nasal Ranger this method was abandoned in favour of odour intensity observations according to the German VDI standard odour intensity scale (Verein Deutscher Ingenieure, 1992).

5.2 Odour intensity observations

The odour intensity observations indicated shorter distances to the odour detection thresholds in calm and near calm conditions. The observed odour intensities were also less strong at closer distances to the piggeries than in windier conditions. Buoyancy of the odour plume from both piggery sheds and ponds may be factor behind this. In calm situations where the ambient temperature is lower than the air being vented out of a piggery shed or the air having passed over an effluent pond (heated by biological activity) buoyancy will lift the odour plume. The contribution of buoyancy in odour dispersion modelling from poultry sheds has been explored (Omerod et al., 2003). and showed to have an effect on near source odour concentrations in AUSPLUME modelling. More recent computational fluid dynamics modelling work on buoyant plume rise from cooling ponds suggests that the plume buoyancy would produce a reduction in ground level concentrations also in the far field from the source (Taylor, 2007). The lower the wind speed and the greater the temperature difference between the ambient air and the source the greater the contribution of buoyancy in the dispersion can be expected. These are conditions which are difficult to model in conventional dispersion models.

5.3 Odour dispersion modelling – Level 2 Assessments

5.3.1 Comparison Level 1, Level 2, State and NEGP Separation Distances

The comparison of the results of the Level 2 separation distances based on dispersion modelling for State and NEGP odour assessment criteria clearly shows that there is no consistency in the predicted separation distances between the different State odour impact assessment criteria. The difference in the predicted separation distance between the largest and smallest predicted separation distances for the different State criteria is a factor of about 2.

It is also clear that the results for the NEGP Level 2 odour dispersion modelling assessment criteria show a decrease compared to the Level 1 separation distance for the deep litter housing piggery, piggery A, which would be anticipated. Whereas the piggeries with effluent treatment ponds show Level 2 separation distances at the same distance or even beyond the Level 1 separation distances depending on the wind direction. This is contrary to the stated NEGP separation distance methodology. It appears from the dispersion modelling results alone that the NEGP separation distance methodology is appropriate for deep litter housing piggeries but not for piggeries with effluent ponds.

The results of the field odour observations which are discussed in detail in the field observation sections tend to confirm that the NEGP separation distance methodology is appropriate for deep litter housing piggeries, but not for piggeries with effluent ponds. The observed odour from piggeries with effluent ponds appear not to travel as far as predicted in the Level 2 dispersion modelling assessment. The field odour observations indicate that the Level 2 assessment overestimates the odour impact affected area for odour from piggery ponds. Hence the alternative hypothesis that the Level 1 separation distances would be underestimating the conservative separation distances appears unlikely.

Considering these results contradict the expected reduction of separation distance going from Level 1 to Level 2 and the piggery odour field observations it appears perceptible that the NEGP separation distance methodology for piggeries with effluent ponds is flawed. The cause for this is either the assumed pond odour emission rates are too high, or the dispersion model does not disperse and account for the emitted odour in a realistic manner.

5.3.2 Reasons for over predictions of odour from piggery ponds in Level 2 assessments

The reasons for the apparent over prediction of odour impact were investigated and traced to:

- a combination of factors in the NEGP pond odour emission rates scheme;
- the quality of the meteorological data used in the dispersion modelling; and
- dispersion model performance

In the NEGP pond odour emission rate scheme the pond odour emission rates are specified for each hourly wind speed and stability class in the meteorological data file used in the dispersion modelling. The pond odour emissions rate scheme (see Table 21) is set up with large variability in odour emission rates for six wind speed classes for wind speeds up to 3 m/s for each stability class. With such fine differences in the input for the meteorological data for the odour emission rate scheme the calculated emission rates have become highly sensitive to the meteorological data. If the meteorological data file contains slightly higher wind speeds and less stable stability classes than for the actual conditions higher odour emission rates will be used in the modelling than is representative of the site. Unfortunately the accuracy of meteorological files used in dispersion modelling in the low wind speed register can be questioned, especially since TAPM over predicts low wind speeds in night time conditions (Luhar, 2007).

Considering the uncertainty around piggery pond odour emissions (Department of Primary Industries and Fisheries, The National Centre for Engineering in Agriculture, 2004) the NEGP pond emission rates scheme appears to be over detailed. It is stated in the NEGP guidelines that the pond odour emission rate scheme has not been verified (Nicholas et al., 2003). We strongly recommend that the pond emission rate scheme should be at least revised with the intension of making the pond odour emission factors less sensitive to wind speed and stability class variations. It is good practice in modelling to resort to a simpler approach in uncertain situations rather than applying a more complex, less understood approach (Pacific Air & Environment, 2003a).

The APL pond odour emission rate scheme may be compatible with the odour measurements the scheme is based on, but the scheme does not appear to perform well in dispersion modelling with AUSPLUME, which is important. Odour assessment contains several steps from sampling to modelled odour impact evaluation. There are assumptions and error margins involved for each step. Currently there is no defined nationally accepted odour assessment methodology that for instance recognizes differences in results from sampling techniques and reflects this in the assessment criteria odour levels. Odour assessments should be approached as package deals and this is the view put forth by the odour industry community.

Since the pond odour emission rates are dependant on the stability class, wind speed and the time of year, the accuracy of the pond odour emission rates is dependant on the quality of the meteorological data used for the dispersion modelling and for the determination of the stability classes. Hence, the quality of the meteorological data is a very important factor for the Level 2 separation distance calculation method especially in situations with odour assessment criteria in the very high percentiles where small inaccuracies in meteorological data significantly bias the modelling results.

5.3.3 Quality of meteorological data for dispersion modelling and origin of meteorological data files

It could be argued that it is up to the piggery developer and the consultant performing the odour dispersion modelling to provide site specific or representable meteorological data of high enough quality to apply to the pond odour emission rate scheme. General guidance on selection of representative meteorological data is given in "Guidance on Meteorological Data for Dispersion Modelling" (Pacific Air & Environment, 2003). However current generally accepted methodologies for deriving dispersion modelling meteorological data appear to lack certainty in measuring/predicting/determining dispersion modelling parameters which become very important in odour dispersion modelling using ground level sources such as piggery ponds where emission rates are determined by the meteorological data. This is especially the case for piggery ponds, because of the range of low wind speeds which is specified in the NEGP piggery pond odour emission rate scheme.

If meteorological data is not available for the site for which the odour dispersion modelling is to be conducted, which most often is the case, caution must be exercised in obtaining meteorological data for the site. The common option in this situation is to either use TAPM generated meteorological data or process a representative observational data file from somewhere within a radius of 20 to 30 km. This raises the question if there is any difference between observational and generated meteorological data for dispersion modelling.

The quality of the meteorological data used in dispersion modelling is not a new issue. It has been shown that meteorological data files for different years can produce variations up to 10% for 99.9 percentile ground level predictions (Cook and Collins, 2002). However, the quality of the meteorological data used for dispersion modelling of odour from piggery ponds using the NEGP pond odour emission rate scheme can produce variations of ground level concentrations and resulting separation distances of significantly larger factors.

5.3.4 Comparison of result with different meteorological data files

In order to address the topic of whether observational meteorological data is more accurate or reliable for dispersion modelling than TAPM generated meteorological data a comparison was conducted in the study. The result of the dispersion modelling for Piggery C for the TAPM generated meteorology was compared to the result of the meteorological data for Piggery C from a weather station located some 10 km from the site. The wind speeds for both of these meteorological data files were compared to the Big River Pork abattoir meteorological data (see Figure 3, Figure 6 and Figure 7). The evaluation showed that significant differences in the data between observations and TAPM generated data concerning the main dispersion drivers: wind speed, stability class and mixing height can cancel each other out and produce similar end results of ground level concentrations. This result is presented in Figure 13.

For the TAPM meteorological file the lowest predicted mixing height was the constraining parameter for the near maximum ground level concentrations whereas for the results for the observational meteorological data an over representation of low wind speeds was the constraining parameter for the near maximum ground level concentration. This over representation of wind speeds was identified by comparison of the data with the Big River Pork meteorological data and by field experience on site.

TAPM predicts a minimum mixing height of 25m while the South Australian EPA endorsed AUSPLUME meteorological data files have a minimum mixing height of 111 m. The difference in the mixing height for these data files was a factor of about four. This difference in the mixing height translated to a decrease in the predicted ground level odour concentration by a factor of two for the dispersion modelling result assessed against the South Australian odour criteria for the TAPM meteorological data using a minimum mixing height of 100 m. This result is presented in Figure 12. (There also appears to be some inconsistencies between mixing height, wind speeds and stability class predictions in TAPM AUSPLUME meteorological file outputs. In the TAPM generated meteorology for 2003 used in this study for 2nd March from the hour 01:00 to 03:00 a wind speed of 3.7 m/s was predicted for D class stability for a mixing height of 25m. The mixing height in these conditions at the site should be higher.) The minimum recommended mixing height

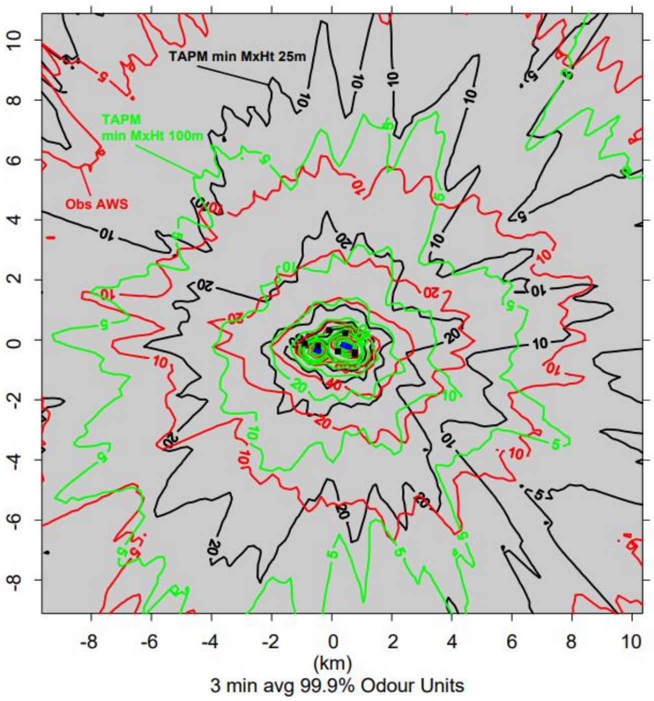

Figure 12 Differences in ground level concentrations due to meteorological data variations.

The accuracy in instrumental observations of wind speeds might exceed TAPM predictions especially in the lower wind speed categories (Luhar, 2007). For this to apply to AUSPLUME dispersion modelling the weather station used for the comparison must be sited accordingly to standard and in a location representative for the local or regional area. It can be difficult to evaluate the representativeness of meteorological data from one site to another if there is little data available in the region.

Meteorological weather stations located within a reasonable distance of 20 km or so from the piggery site in question with similar exposure to the site for the odour assessment might still show significant variabilities in the meteorological data due to minor differences in the station exposure. Despite the uncertainties of accuracies in TAPM generated site specific meteorological data, observational data is not necessarily more accurate if the observational data used not is truly representative of the site conditions.

5.3.5 Stability class determining methods

There are also issues regarding the meteorological parameters of stability class and mixing heights. These parameters are not measured directly but are calculated according to various methods depending on what data is available. The methods for determination of stability class and calculation of mixing height might produce different results for TAPM and for observational data depending what observational meteorological data is available. Even slight differences in the meteorological data when applied to piggery pond odour dispersion modelling assessed against near maximum percentile odour assessment criteria can produce significant differences in the modelling prediction outcome with overestimation of odour impacts and separation distances as a result.

There are different stability class determination methods and for dispersion modelling with emission rates determined by stability class it is important the stability class in the AUSPLUME meteorological data file is derived with the same method as was used for the emission rate scheme (PG method for the NEGP). If an alternative method is used inconsistencies between meteorological conditions and odour emission rates is likely to arise, with the likely consequence of overestimation of odour impacts. The same method should be used for determination of stability class for the meteorological file as used for the emission data to avoid inconsistencies. However, the method used for determination of stability class for observational data is often determined by the available meteorological data.

5.3.6 Model sensitivity to meteorological parameters

Dispersion of piggery odour is mainly driven by stability class, wind speed and mixing height. In order to illustrate just how sensitive in AUSPLUME the resulting ground level concentration prediction is to the meteorology three plots have been presented in Figure 13, Figure 14, Figure 15 below. These plots were prepared by allocation of discrete receptors downwind north of piggery C from 500 m to 3500 m from the sources and all the wind directions in the meteorological data file were set to southerly. Hence the ground level concentration predictions were gathered for all conditions modelled. The plots illustrate the sorted data of the ground level concentrations for 8760 hours. The data was first sorted accordingly to hourly stability classes (the data is plotted first for stability class A then B then C etc to stability class F).

For each stability class the data was subsequently sorted first for wind speeds in Figure 13 and mixing height in Figure 14 increasing from lowest to highest wind speed or mixing height for each stability class. Figure 13 and Figure 14 are plotted for pond odour emission rates using variable NEGP emissions whereas Figure 15 is plotted for constant pond odour emissions. Firstly it can be seen how the predicted ground level concentrations strongly rise for the lowest wind speeds and mixing heights for all stability classes. As the stability class increases (goes towards F) it is expected that the resulting ground level concentration should increase as dispersion conditions are less favourable. This behaviour can be observed for the constant emissions in Figure 15 but is less pronounced for the variable emissions in Figure 13 and Figure 14. This is due to the variable NEGP pond odour emission scheme.

It is clearly obvious that the highest odour concentration events occur in D class stability conditions for the modelling predictions. This is somewhat contrary to what normally would be expected from AUSPLUME dispersion modelling with the highest odour events normally occurring in more stable F class conditions. Either it is the dispersion conditions that dictate the highest concentration events or the odour release from the effluent ponds. The field observations showed less odour impact in calm conditions. Other factors might be relevant in low wind speed conditions however. It is likely that buoyancy of the odour plumes might be relevant in low wind speeds but buoyancy effects are not accounted for in the modelling.

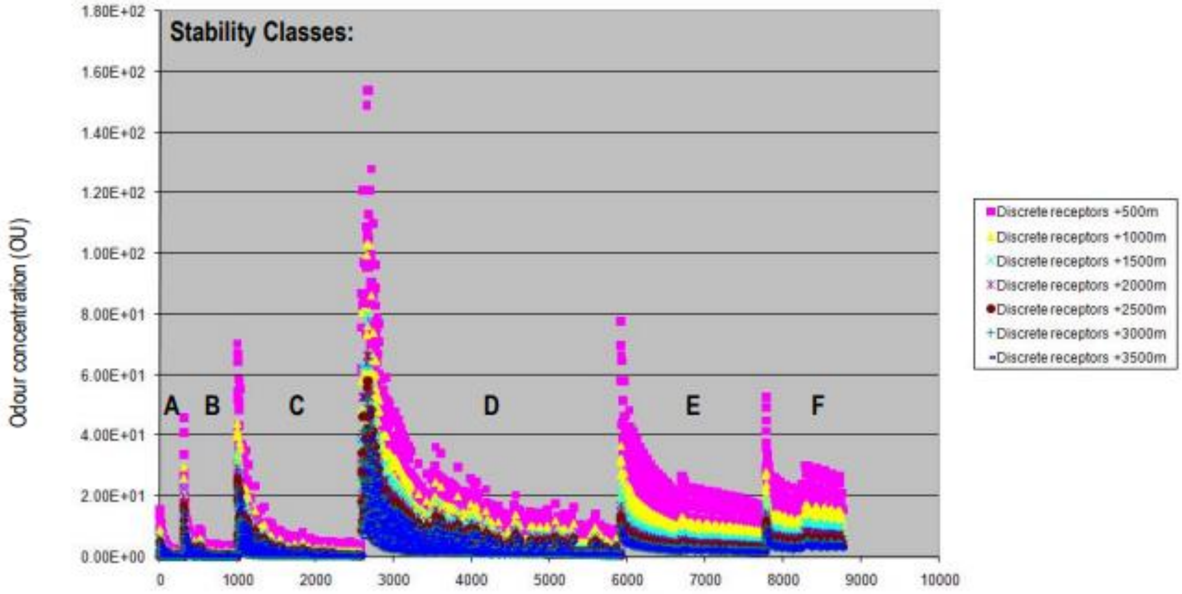

Figure 13 Concentrations of variable emissions sorted by stability class and wind speed

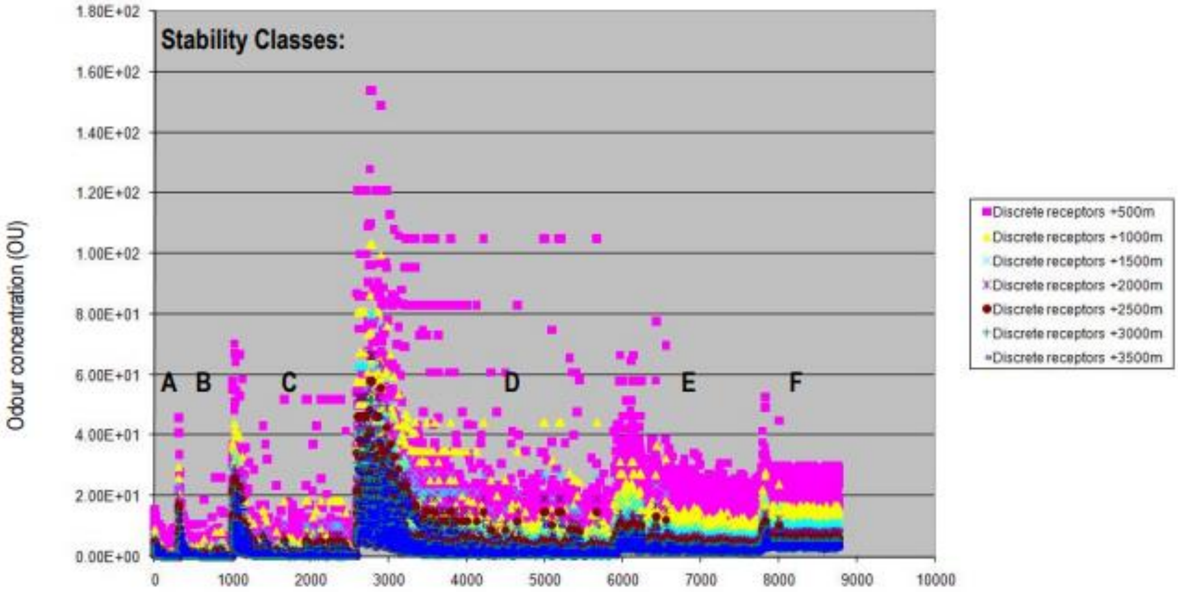

Figure 14 Concentrations of variable emissions sorted by stability class and mixing height

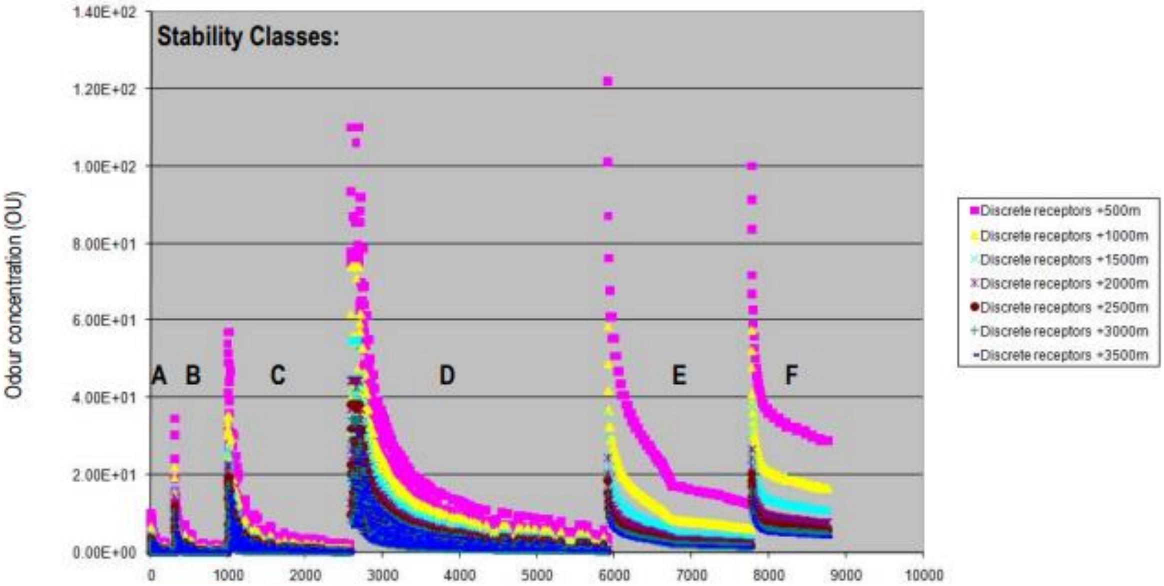

Figure 15 Concentrations of constant emissions sorted by stability class and wind speed

It appears from Figure 13 to Figure 15 and the field observations that neither TAPM generated meteorological data nor representative observational data is accurate enough for near maximum percentile odour impact assessment. Considering the low minimum predicted mixing heights TAPM generated AUSPLUME meteorological file outputs can be considered as highly conservative when applied to ground level source odour modelling. In this regard observational data may appear more accurate than TAPM generated data but this is not necessarily the case if the observations show an over representation of lower wind speeds than expected in the area due to AWS siting issues.

5.3.7 Dispersion model performance in relation to odour assessment criteria

It is commonly recognized that Gaussian plume dispersion models have prediction accuracy within a factor of two and that the model performance is especially limited in low wind speed and stable conditions (New Zealand Ministry for Environment, 2004). It is also recognized that annual maximum or near maximum predicted ground level concentrations are likely to be products of inaccuracies in the meteorological data file. It is also recognized that the dispersion model application for ground level sources is quite different compared to stack emissions from point sources. Odour dispersion modelling results from ground level sources such as piggery related sources is potentially quite uncertain compared to dispersion modelling from stack point sources.

Considering the Gaussian dispersion model's poor recognized performance for prediction of ground level concentrations in near calm stable conditions it appears anomalous that many of the state odour impact assessment criteria actually are assessed against the 99.9 percentile which is a near maximum value. Assessment of odour dispersion modelling results, especially from ground level sources, against a lower percentile would be more theoretically satisfying. A near maximum assessment criteria in effect applies AUSPLUME to conditions in which the model's performance is questionable. Assessment against a lower percentile would increase the AUSPLUME's prediction performance for separation distances.

It has been shown that AUSPLUME modelling results are very sensitive to near maximum percentiles for low wind speed conditions and that the highest advisable percentile based on model performance to assess AUSPLUME results for ground level sources against is the 99.5 percentile (Rayner, 2007). This sensitivity is also illustrated in Figure 13 above where the predicted ground level concentrations increase very steeply for each stability class for the lowest wind speeds.

The 98th percentile is commonly used in Europe as odour assessment criteria and is based on community consultations and odour complaint histories along with considerations of model performance (van Harreveld et al., 2005). It has been shown that odour annoyance from complaint histories and community consultations do give the best agreement with modelling predictions for the 98th percentile (Pacific Air & Environment, 2003b). Assessment against the 98th percentile has been argued for by the odour industry with increasing conviction since the 2002 Enviro Convention in Melbourne.

A near maximum odour assessment criteria does not address the frequency of the odour event but a worst case scenario under conditions when the AUSPLUME model may be inaccurate. A lower percentile such as the 98th percentile does allow for frequency of odour events as has been shown in European odour annoyance community consultation work.

A summary of the underlying factors for odour annoyance resulting in complaints are often referred to as the FIDOL factors:
Frequency of odour events Intensity of odour events
Duration of odour events
Offensiveness of the odour
Location of odour

Near maximum odour concentration as normally predicted for a year of meteorological data generally occur in the most stable conditions which generally occur after midnight before sun rise. A lower percentile allows for conditions to be assessed in which the likely-hood is higher that receptors are exposed. The 98th percentile also allows for local meteorological patterns to feed into and be accounted for by the assessment criteria.

Any issue regarding perceived loss in conservatism in the resulting separation distance from the odour impact assessment criteria in changing from the 99.9th or 99.5th percentile can be adjusted by selection of the odour concentration for the odour assessment criteria. This is clearly illustrated in the Figure 8 to Figure 10.

It is commonly recognized that the performance of Gaussian plume dispersion models in near calm stable conditions is poor. The higher the percentile the assessment is made against the more sensitive the predictions are to inconsistencies in the meteorological data or inaccuracies in odour sampling or analysis. By assessing against the 98th percentile inconsistencies in the meteorological data are filtered out to a higher degree, which generally increases the reliability in the modelling predictions since the assessed modelling results are for conditions in which the AUSPLUME model provides more reliable results.

5.3.8 *Conclusions*

- The NEGP separation distance assessment method applies well to deep litter housing type piggeries.
- The Level 2 assessment method (NEGP pond odour emission rate scheme) leads to over predictions of odour impacts and separation distances from piggery ponds.
- It is difficult to derive a representative meteorological data file that is accurate enough to correctly use the pond odour emission rate scheme and model the assessment for near maximum percentiles.
- It can be difficult to evaluate the representativeness of an AUSPLUME meteorological data file, whether derived for observational data or TAPM.
- Meteorological data for dispersion modelling is not by default more accurate for observational data than for TAPM generated data.
- The NEGP piggery effluent pond odour emission rate scheme is very sensitive to meteorological data of common poor quality used in odour dispersion modelling studies. This sensitivity is also exaggerated by the near maximum state odour impact assessment criteria whereas the NEGP specifies the 98th percentile.
- The NEGP piggery effluent pond odour emission rate scheme should be revised with the aim of making the scheme less sensitive to low wind speeds and with a reduced influence of the stability class. Presently the dispersion modelling suggests highest odour impact in low wind speed conditions whereas the observations suggest differently. This highlights Gaussian plume model's limitations in low wind speeds.
- Gaussian plume models should not be used for determination of separation distances for the meteorological conditions for which the model's ground level concentration prediction performance is poor. This is however often the case for assessment against near maximum percentiles.
- Odour assessment criteria should recognise differences in results due to the odour sampling technique used.
- The 98th percentile is a better and more reliable odour impact assessment criteria for AUSPLUME since it factors in: - Gaussian plume models performance capabilities and consequently better reliability of dispersion modelling results; - the quality of commonly available meteorological data for dispersion modelling; - local meteorology in the assessment; - frequency of odour events; - higher likelihood of exposure of sensitive receptors; and - a better comparison with community surveys and complaint histories.

5.4 Evaluation of Level 1 & Level 2 Separation Distances

It could be argued that no observations were made in the in conditions corresponding to the predictions for the 99.9th and 99.5th percentile and that the observations were carried out in conditions that more resembled the 98th percentile conditions and that the better fit to the 98th percentile would be due to that cause. For this study forecasts were monitored for the better part a year for selection of the worst possible dispersion conditions for field observations. Given that effort one can conclude that odour observations for verification of dispersion modelling in conditions corresponding to percentiles higher than the 98th percentile would be extremely difficult achieve. An alternative method would be to deploy a series of E-noses (E-nose, 2007) for continuous odour monitoring in the field

6. Implications & Recommendations

1. Determine the effectiveness of the Nasal Ranger field olfactometer in determining odour strengths downwind of piggeries in conditions favouring long distance transmission of piggery odours.
    - The Nasal Ranger (the nasal seal in particular) has an inherent smell which was found to act as a masking odour complicating the detection of piggery odour.
    - The Nasal Ranger does not offer a viable alternative method for assessing piggery odour.
    - Piggery odour is a complex odour which is difficult to detect at the detection threshold in the Nasal Ranger.
    - The Nasal Ranger is not suitable for odour observations for evaluation of odour dispersion modeling.
    - Stable conditions is an imperative condition for Nasal Ranger observations given the time required for an observation.
2. Determine the effectiveness of a panel of calibrated noses in determining the extent and intensity of piggery odour travel, particularly at times of minimum dispersion conditions.
    - Minimum dispersion conditions were found challenging to forecast.
    - Odour intensity observations work well for tracking odour plumes for determination of distance of odour travel till detection threshold.
3. Compare results of NEGP Level1 and Level 2 buffer distance calculations against field observations of odour travel and odour levels measured by the Nasal Ranger. Piggery odour emissions for Level 2 assessment will be calculated from recommended emissions in the APL Odour Research Database, based on pig numbers.
    - The NEGP piggery pond odour emission rate scheme was found exceedingly sensitive to meteorological data. It is a strong recommendation that the NEGP piggery pond odour emission rate scheme should be revised with the intension of making the scheme less sensitive to low wind speed and stability class variations which will reduce the over predictions.
    - Compared to the odour intensity observations of distance of odour travel to detection threshold for all of the piggeries the NEGP Level 1 separation distances were found to provide the intended high level of protection of community amenity.
    - The odour intensity observations of distance of odour travel to the detection threshold compared well with the NEGP Level 2 separation distances for the deep litter housing piggery, Piggery A.
    - • For the piggeries with effluent treatment ponds the NEGP Level 2 separation distances were found over predicted compared to the odour intensity observations of odour travel to detection threshold.
4. Test the effectiveness of the CSIRO TAPM software in determining a synthetic meteorological dataset suitable for input to an air dispersion model.
    - There is no major difference in dispersion modelling results between TAPM generated meteorological data or regionally representative observational data. Whichever data set represents the site best should be used.
    - The quality of the meteorological data in odour dispersion modelling of piggery effluent ponds is paramount.
    - Site specific observations offers better reliability than generated or regional meteorology but extra care must be exercised in determination of stability classes

due to the effluent pond emission odour emission rate scheme's dependency on stability classes.
- It can be difficult to assess the representativeness of meteorological data from one site to another and this makes it difficult to control the level of conservatism comparing a Level 2 assessment to a Level 3 assessment.

5. Compare results from the AUSPLUME dispersion model for outputs of a 1 hour average, 99.9%, 99.5%, 98% and 3 minute average 99.9% and 99.5% criteria in order to cover odour criteria for a number of States in addition to the NEGP Appendix A4.6 odour impact criteria.
    - Differences in separation distances of factor of about 2 was predicted by AUSPLUME for the different state odour impact assessment criteria.
    - The 98th percentile offers a more robust odour impact assessment criterion which produces more reliable predictions of separation distances especially for piggeries with effluent ponds than the 99.9th and 99.5th percentile for AUSPLUME.
    - The 98th percentile recognizes AUSPLUME's limited performance in low wind speed conditions better than the 99.9th and 99.5th percentiles.

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